# Herpetofauna Survey of Petrified Forest National Park, Arizona

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**Abstract.** We present the results of an amphibian and reptile inventory conducted in 1997-1998 at Petrified Forest National Park. Using visual encounter surveys, pitfall trapping, artificial cover boards, and night driving techniques, we recorded 1,628 individual amphibians and reptiles (exclusive of larval amphibians) of 23 species. The species total includes seven amphibians, nine lizards, and seven snakes. Two of the lizard species (both of them whiptail lizards, genus *Cnemidophorus*) are new to the park. Small populations of the little striped whiptail are the first records for Petrified Forest, and also the first reported occurrences in Navajo and Apache counties. The New Mexico whiptail (probably introduced) is the first report for the state of Arizona. Petrified Forest National Park has a diverse herpetofauna, with species from varied biogeographic regions (Great Plains, Great Basin, and southern deserts and grasslands) occurring together in the park. The park is one of the few remaining large protected areas of grassland habitat on the southern Colorado Plateau, and supports regionally rare grassland amphibians and reptiles.

**Key words:** amphibians, reptiles, Petrified Forest National Park, Arizona, Little Colorado River basin, grasslands, inventory, habitat associations, biogeography.

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## INTRODUCTION

Accurate inventory data, including information on the occurrence of plant and animal species, their distribution, abundance, and habitat relationships, is one of the essential starting points for informed protection and management of natural resources. In spite of long-standing policy (e.g. NPS-75; National Park Service 1992) and discussion on the importance of resource inventory, many National Park Service areas remain seriously deficient in even basic inventory data (e.g. Stohlgren and Quinn 1992). The need for baseline natural resource data is especially acute in areas and habitats that have been extensively disturbed, as is the case with grassland habitats on the southern Colorado Plateau (Kearney and Peebles 1960, Lowe 1964, Brown 1994).

Despite protecting a large area of native grassland and other habitats important to amphibians and reptiles, Petrified Forest National Park has never had a herpetofauna inventory. The grassland and grass-shrub habitats of the Petrified Forest area are known to support regionally rare species, such as Couch's spadefoot (*Scaphiopus couchii*) and the milk snake (*Lampropeltis triangulum*) (Stebbins 1985). For the southern Colorado Plateau region, there have been no previous intensive studies of grassland amphibian and reptile assemblages. The few published reports on amphibians and reptiles in the region only document species occurrence within a general area (e.g. Eaton 1935, Harris 1963).

The goal of this study was to conduct a complete species inventory (after Scott 1994) of amphibians and reptiles at Petrified Forest, compare sampling methods in grassland and grass/shrub habitats, and describe the herpetofauna in terms of relative abundance, habitat associations, and biogeography. In addition to providing inventory data to park resource managers, this study is important for its contribution to understanding the distribution and ecology of amphibians and reptiles in the region. Because Petrified Forest is both geologically and floristically characteristic of a large portion of the southern Colorado Plateau, and in particular of the Little Colorado River basin of northeastern Arizona, results of this study contribute to understanding the fauna of the wider geographic region.

## METHODS

### *Study Area*

Petrified Forest National Park is located on the south-central Colorado Plateau, straddling the border of Navajo and Apache counties east of Holbrook, Arizona (Fig. 1). The park encompasses 38,133 ha, and lies within the Little Colorado River basin. Elevations vary from 1,617 m along the Puerco River, which bisects the park, to 1,900 m at the summit of Pilot Rock in the extreme northwestern corner of the park (USGS 1981, 1982). Topographically, the park ranges from rolling, sandy grasslands to mesas and extensively eroded badlands.

Petrified Forest has warm summers and moderately cold winters. Average summer (July) high temperature is 33.6°C, with overnight lows averaging 15.6°C. In January, average daytime high temperature is 8.4°C, with an average low of -6.6°C. Mean annual precipitation is 24.4 cm, much of it coming in the form of monsoon

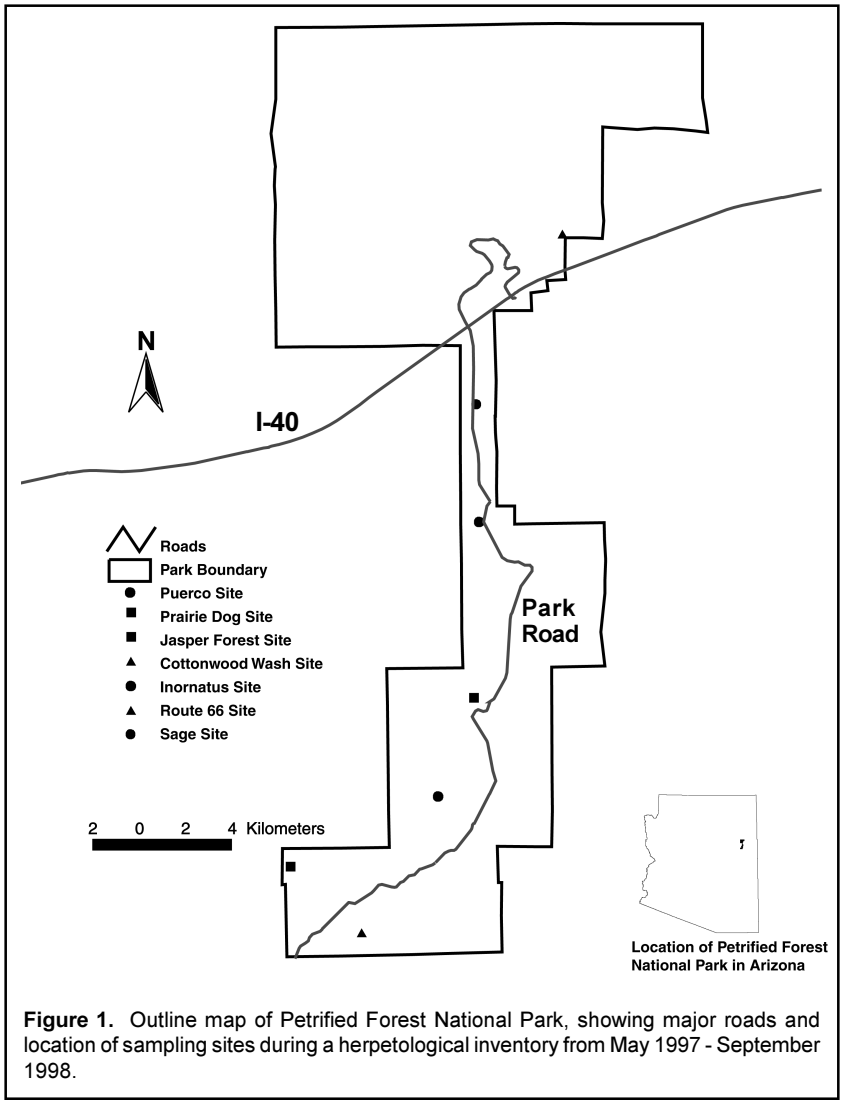


**Figure 1.** Outline map of Petrified Forest National Park, showing major roads and location of sampling sites during a herpetological inventory from May 1997 - September 1998.

thunderstorms in July-September. Spring and early summer are dry, and often extremely windy.

Petrified Forest lies within the Plains and Great Basin Grassland biome of Brown and Lowe (1980). Park vegetation is a complex interdigitation of arid grasslands, grass-shrublands, dune communities, and badlands and other barren habitats. Areas of juniper woodland and riparian trees and shrubs are limited in area, but add significantly to the park's biological diversity. For analysis of amphibian and reptile distribution, we recognized a number of broad vegetation types: grasslands, shrub communities (primarily shrub-grasslands), dune communities, riparian com-

munities (Puerco River), and juniper woodland. Dominant and characteristic perennial plant species of these habitat types are described in Appendix 1. Two additional habitats for amphibians and reptiles – rocky areas (including rock outcrops and boulder fields) and developed areas – are not based on vegetation associations, but may support distinctive associations of amphibians and reptiles. We do not cover in detail badlands, desert pavement, and saline flats because of their limited amphibian and reptile fauna.

## *Field Methods*

We used a variety of field survey methods at Petrified Forest during the spring, summer, and early fall, when amphibians and reptiles are most active. Sampling was initiated in July 1997 and completed in September 1998. We trapped amphibians and reptiles using four-liter (one gallon) pitfall traps (Fellers and Drost 1991), 19-liter (five gallon) pitfall arrays with drift fences (Campbell and Christman 1982, Jones 1986, Corn 1994), and artificial cover boards (Fellers and Drost 1994). We placed combinations of traps and cover boards at seven sites located in different habitats throughout the Park. A typical installation consisted of an array of four 19-l pitfall traps arranged in a 'Y' shape, with a metal flashing drift fence connecting the four traps (Jones 1986). The Y-array was paired with a 135 m transect of five 4-l pitfall traps, alternating with five cover boards, each measuring 60 cm x 120 cm x 2 cm (¾-inch plywood). Spacing between traps and boards was 15 m. We sampled trap sites twice a month. During each session, pitfalls and arrays were open (lids removed) for four consecutive nights, and checked at least every other day. Cover boards were checked once per sampling session.

We conducted night driving surveys (Mendelson and Jennings 1992, Rosen and Lowe 1994, Shaffer and Juterbock 1994) on the main park road, which runs the entire length of the Park from north to south (Fig. 1). Surveys generally consisted of driving the length of this road (45 km one way), but occasionally included other paved and unpaved roads. Start time of surveys varied from official sunset to about 10 p.m., with most surveys completed by 11 p.m. We completed at least eight night surveys each month, except in the early and late season, when amphibian and reptile activity was low.

Visual encounter surveys (VES; Crump and Scott 1994) were primarily used to survey for diurnal lizard species. We selected areas for these surveys that would sample the range of habitats and geographic regions within the Park, with particular attention being given to searching areas not sampled by other methods. For example, we did not extensively trap sites or conduct night drives in much of the northern section of the Park because of its remoteness as part of a large wilderness area. Time-constrained searches and general surveys comprised our VES. Time-constrained searches covered relatively small, predefined areas in single habitat types, each of which was searched for a period of about an hour. General surveys typically covered larger areas, were not restricted to single habitat types, and were not time-limited. These surveys were conducted in areas away from roads and away from our

main sampling areas. All areas covered by visual encounter surveys were recorded on 1:24,000 scale maps, along with data on time, habitat, and species.

Besides these specific sampling methods, we also recorded data from general field observations, which included turning natural and artificial cover, animals seen on the park roads during the day, and observations of amphibians and reptiles during the course of other fieldwork. We also solicited observations from personnel working in the park, including National Park Service staff and other field researchers.

## RESULTS

### *Sampling Effort*

Distribution of sampling effort varied by month for the different sampling techniques (Table 1). Sampling effort for pitfall and array traps is measured in trap-days ((number of traps open) x (number of days they were open for)), and for artificial cover boards, number of times the boards were checked (i.e., turned to look for animals underneath). Sampling effort totaled 1,811 trap-days for 4-l pitfalls, 1,657 trap-days for 19-l array traps with drift fences, and 915 checks of artificial cover boards.

We spent 135 hours conducting visual encounter surveys, including general surveys and time-constrained searches (TCS). During the first year, we concentrated on general surveys of large areas of the park on foot, to provide a broad overview of the geographic extent of Petrified Forest National Park, and its range of habitats. Some of the more remote areas sampled by general surveys included Digger Wash and Pilot Rock in the northwest corner of the park, the area north of old Route 66 on the northeast park boundary, the Blue Mesa area along the park's eastern boundary, and the south Petrified Forest Wilderness area in the southeast corner of the park.

**Table 1.** Monthly sampling effort for a survey of amphibians and reptiles at Petrified Forest National Park, Arizona, between July 1997 and September 1998. Sampling effort for pitfall and drift fence arrays is recorded as trap-days, and sampling effort for cover boards is measured as number of times the boards were checked (see text). Effort for visual encounter surveys, including time-constrained searches (TCS) and general surveys, is measured in hours. Effort for night driving is number of km driven.

| | Jul 97 | Aug 97 | Sep 97 | Oct 97 | May 98 | Jun 98 | Jul 98 | Aug 98 | Sep 98 |
|---|---|---|---|---|---|---|---|---|---|
| Pitfall traps | 0 | 55 | 199 | 0 | 320 | 320 | 319 | 469 | 159 |
| Drift fence arrays | 0 | 60 | 199 | 0 | 288 | 284 | 285 | 421 | 144 |
| Cover boards | 0 | 0 | 30 | 10 | 145 | 160 | 240 | 210 | 120 |
| TCS | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 | 12.7 | 5.0 | 8.5 | 0.0 |
| General survey | 13.9 | 17.7 | 5.6 | 0.4 | 6.3 | 24.4 | 14.0 | 8.4 | 14.2 |
| Night driving | 222 | 968 | 1,022 | 142 | 87 | 713 | 628 | 1,161 | 625 |

TCS were initiated in the second year of the project. Just over 30 hours of time-constrained searches were conducted in 1998.

We began night drive surveys in July 1997, with a total of 2,354 km driven in 1997, mostly along the main north-south park road. We drove a total of 3,214 km from May through September of 1998, primarily along the main park road. Over the 2-year study period, total road survey sampling amounted to 5,567 km.

## *Amphibian and Reptile Diversity*

We sighted or captured 1,628 individual amphibians and reptiles during this study, of 23 species. These included seven amphibians (one salamander and six spadefoot and true toads), nine lizards, and seven snakes (Table 2; nomenclature follows the federal interagency Integrated Taxonomic Information System or ITIS; see http://www.itis.usda.gov/access.html). We found all but one of these 23 spe-

**Table 2.** Amphibians and Reptiles of Petrified Forest National Park, based on an inventory study conducted in 1997 and 1998. Names follow ITIS (see text). Some familiar names have been changed recently, including: *Pituophis melanoleucus* changed to *P. catenifer*, and *Scaphiopus multiplicatus* and *Scaphiopus bombifrons* changed to *Spea multiplicata* and *Spea bombifrons*.

**AMPHIBIANS**
Salamanders
- Tiger Salamander (*Ambystoma tigrinum*)

Frogs and Toads
- Couch's Spadefoot (*Scaphiopus couchii*)
- Plains Spadefoot (*Spea bombifrons*)
- Southern Spadefoot (*Spea multiplicata*)
- Great Plains Toad (*Bufo cognatus*)
- Red-spotted Toad (*Bufo punctatus*)
- Woodhouse's Toad (*Bufo woodhousii*)

**REPTILES**
Lizards
- Collared Lizard (*Crotaphytus collaris*)
- Lesser Earless Lizard (*Holbrookia maculata*)
- Short-horned Lizard (*Phrynosoma douglasii*)
- Sagebrush Lizard (*Sceloporus graciosus*)
- Eastern Fence Lizard (*Sceloporus undulatus*)
- Side-blotched Lizard (*Uta stansburiana*)
- Little Striped Whiptail (*Cnemidophorus inornatus*)
- New Mexico Whiptail (*Cnemidophorus neomexicanus*)
- Plateau Striped Whiptail (*Cnemidophorus velox*)

Snakes
- Glossy Snake (*Arizona elegans*)
- Night Snake (*Hypsiglena torquata*)
- Common Kingsnake (*Lampropeltis getula*)
- Milk Snake (*Lampropeltis triangulum*)
- Striped Whipsnake (*Masticophis taeniatus*)
- Gopher Snake (*Pituophis catenifer*)
- Western Rattlesnake (*Crotalus viridis*)

cies in the first month and a half of field work, by mid-August 1997. The last species found was the New Mexico whiptail (*Cnemidophorus neomexicanus*), which has a very restricted distribution in the park. This species was first discovered early in the second year, in mid-June 1998. The little striped whiptail (*Cnemidophorus inornatus*) and the New Mexico whiptail represent first reports of these species in the Petrified Forest region, and the occurrence of the New Mexico whiptail at Petrified Forest is the first record of that species anywhere in the state of Arizona (Persons and Wright 1999a; Fig. 2).

### *Comparison of Methods*

The different field techniques used in this study varied widely in their effective-

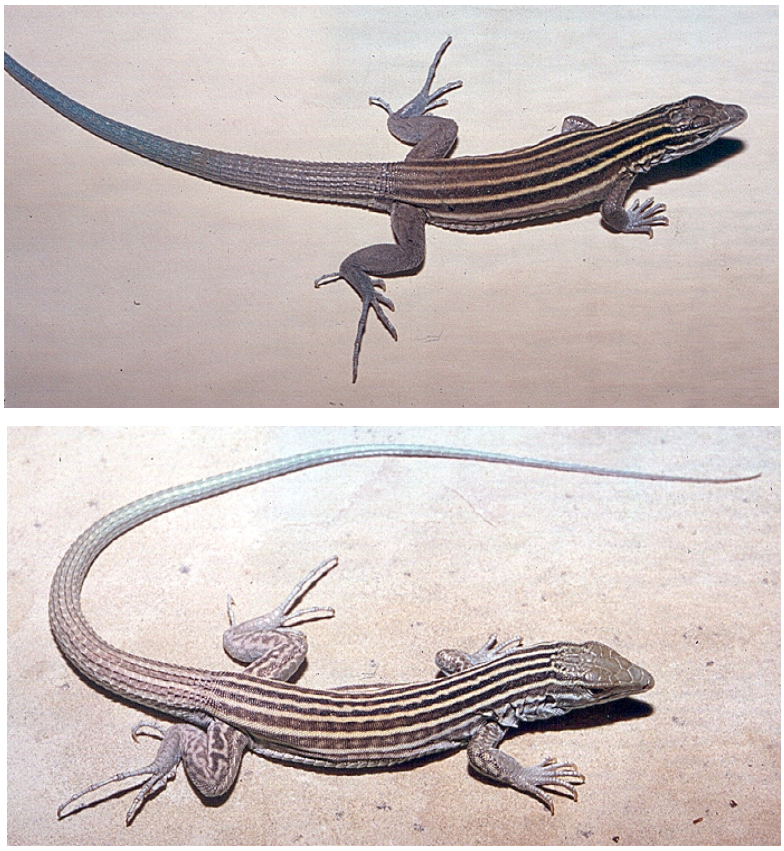

**Figure 2.** *Cnemidophorus inornatus* (above), and *C. neomexicanus* (below), two additions to the known herpetofauna of Petrified Forest National Park and the surrounding region (photos by T. B. Persons).

ness in sampling different species of amphibians and reptiles (Table 3). In general, lizards were most effectively sampled by pitfall and array trapping and cover boards, and by visual encounter surveys (time-constrained searches and general surveys). Moderate numbers of some amphibian species were captured in array traps, though the highest numbers of all species were recorded during night driving surveys. Except for the striped whipsnake (*Masticophis taeniatus*), nearly all of the snakes were

**Table 3.** Comparison of capture totals of different amphibian and reptile sampling methods at Petrified Forest National Park in 1997 and 1998. Methods and sampling effort are as listed in Table 1. Number of species and total number of individuals accounted for with each sampling method are listed for amphibians, lizards, and snakes. Animals not identified to species (e.g., *Spea* sp.) are not listed in the species total, unless they were the only members of that taxon recorded.

| | Pitfall | Array | Cover | TCS | General | Night |
|---|---|---|---|---|---|---|
| Tiger Salamander | 0 | 1 | 0 | 0 | 0 | 5 |
| Couch's Spadefoot | 0 | 1 | 0 | 0 | 0 | 24 |
| Plains Spadefoot | 1 | 14 | 0 | 0 | 0 | 53 |
| New Mexico Spadefoot | 0 | 30 | 0 | 0 | 1 | 191 |
| Spadefoot, *Spea* species | 0 | 8 | 0 | 2 | 7 | 1 |
| Great Plains Toad | 0 | 8 | 1 | 0 | 2 | 70 |
| Red-spotted Toad | 0 | 0 | 0 | 0 | 0 | 12 |
| Woodhouse's Toad | 0 | 0 | 0 | 0 | 0 | 3 |
| **Amphibian species:** | **1** | **5** | **1** | **1** | **2** | **7** |
| **Total amphibians:** | **1** | **62** | **1** | **2** | **10** | **359** |
| Collared Lizard | 2 | 5 | 8 | 9 | 23 | 2 |
| Lesser Earless Lizard | 0 | 7 | 3 | 4 | 22 | 4 |
| Short-horned Lizard | 0 | 0 | 3 | 1 | 2 | 2 |
| Sagebrush Lizard | 31 | 45 | 41 | 1 | 19 | 0 |
| Eastern Fence Lizard | 3 | 9 | 8 | 30 | 125 | 0 |
| Fence Lizards, *Sceloporus* sp. | 0 | 0 | 2 | 1 | 15 | 0 |
| Side-blotched Lizard | 1 | 1 | 7 | 15 | 8 | 0 |
| Little Striped Whiptail | 0 | 0 | 0 | 0 | 11 | 0 |
| New Mexico Whiptail | 0 | 0 | 0 | 0 | 5 | 0 |
| Plateau Striped Whiptail | 26 | 28 | 2 | 32 | 186 | 0 |
| Whiptails, *Cnemidophorus* sp. | 0 | 0 | 0 | 8 | 8 | 0 |
| **Lizard species:** | **5** | **6** | **7** | **7** | **9** | **3** |
| **Total lizards:** | **63** | **95** | **74** | **101** | **424** | **8** |
| Glossy Snake | 0 | 0 | 0 | 0 | 0 | 15 |
| Night Snake | 0 | 0 | 0 | 0 | 0 | 33 |
| Common Kingsnake | 0 | 0 | 0 | 1 | 2 | 6 |
| Milk Snake | 0 | 0 | 0 | 0 | 0 | 7 |
| Striped Whipsnake | 0 | 1 | 0 | 0 | 2 | 2 |
| Gopher Snake | 0 | 0 | 0 | 1 | 2 | 47 |
| Western Rattlesnake | 0 | 0 | 0 | 0 | 0 | 28 |
| **Snake species:** | **0** | **1** | **0** | **2** | **3** | **7** |
| **Total snakes:** | **0** | **1** | **0** | **2** | **6** | **138** |
| **Total species:** | **6** | **13** | **9** | **12** | **17** | **18** |
| **Total numbers:** | **64** | **158** | **75** | **105** | **440** | **505** |

found during night driving surveys. Species recorded only during night driving surveys included the red-spotted (*Bufo punctatus*) and Woodhouse's toad (*B. woodhousii*), and glossy snake (*Arizona elegans*), night snake (*Hypsiglena torquata*), and milk snake (*Lampropeltis triangulum*). No other species were detected with only one sampling method, except for the isolated populations of little striped whiptail and New Mexico whiptail, which were only encountered during general surveys.

Small (4-1) pitfall traps, drift fence arrays with large (19 l) pitfall traps, and artificial cover boards were all set out in the same areas, and generally sampled the same fauna. The arrays were much more effective in sampling amphibians, however (Table 3), presumably because the drift fences intercepted individuals moving from place to place. Artificial cover boards were about as effective as array traps for lizards, capturing as many or more individuals of all species except plateau striped whiptail, and recording one species not captured in the arrays (short-horned lizard, *Phrynosoma douglasii*). For approximately equal effort, the 4-l pitfall traps were less effective than arrays or cover boards, capturing fewer species and fewer individuals.

## *Habitat and abundance*

Table 4 lists capture data for the most common species captured at each of the pitfall/array/coverboard sampling sites at Petrified Forest, and Figure 3 shows "capture" (i.e., encounter) rates for the most common species recorded on visual encounter surveys (combined time-constrained searches and general surveys). Both data sets are grouped into habitats as grassland, shrubland, sand/shrub habitat, rock habitat (rocky cliffs and slopes, boulder fields), and riparian habitat. Capture rates varied among the different grassland sampling sites, probably due to wide variation in height and density of grass in the different areas. Jasper Forest and the Prairie Dog

**Table 4.** Capture rates of amphibians and reptiles at pitfall and drift fence array sites at Petrified Forest National Park, Arizona, in 1997-98. Rates are captures per 1,000 trap-nights (see text). Site codes are: COWA-Cottonwood Wash; INOR-Inornatus; JAFO-Jasper Forest; PRDO-Prairie Dog; PUER-Puerco River; RT66-Route 66; and SAGE-Sagebrush. Habitat at the site is in parentheses below the site code. For some sites, a secondary habitat is listed after the first, "main" habitat (e.g. Grass/Rock).

| | JAFO (Grass/Rock) | PRDO (Short grass) | RT66 (Tall grass) | SAGE (Shrub) | COWA (Sand/Shrub) | INOR (Rock) | PUER (Riparian) |
|---|---|---|---|---|---|---|---|
| Plains Spadefoot | 0.0 | 0.0 | 0.0 | 2.1 | 13.2 | 0.0 | 4.7 |
| Southern Spadefoot | 0.0 | 5.6 | 8.3 | 1.0 | 17.6 | 2.8 | 33.0 |
| Collared Lizard | 0.0 | 0.0 | 0.0 | 1.0 | 2.2 | 11.1 | 0.0 |
| Lesser Earless Lizard | 0.0 | 16.7 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Sagebrush Lizard | 0.0 | 5.6 | 0.0 | 48.5 | 28.7 | 2.8 | 0.0 |
| Eastern Fence Lizard | 2.8 | 0.0 | 0.0 | 0.0 | 3.3 | 0.0 | 37.7 |
| Side-blotched Lizard | 5.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Plateau Striped Whiptail | 2.8 | 0.0 | 0.0 | 23.7 | 29.8 | 5.6 | 4.7 |

site are relatively open areas of short grass, while the Route 66 site has much taller, denser grassland. In addition, Jasper Forest has scattered surface rocks, and the presence of extensive burrows at the Prairie Dog site may be important to existing amphibian and reptile populations. Among all of the grassland sites, lesser earless lizard (*Holbrookia maculata*) at the Prairie Dog site had the highest capture rate (Table 4). For visual encounter surveys in grassland, the highest encounter rates were for plateau striped whiptail (*Cnemidophorus velox*), followed by lesser earless lizard (Fig. 3).

At the Sagebrush sampling site, sagebrush lizards (*Sceloporus graciosus*) had the highest capture rate, followed by plateau striped whiptails. The same two species were most numerous in visual encounter surveys in shrub habitats. The Cottonwood Wash sampling site, in deep sand with scattered shrubs in the southern part of the park, was the most productive trapping site at Petrified Forest. We captured four lizard species and two spadefoot toad species at the site, with nearly equal numbers of plateau striped whiptails and sagebrush lizards. In visual encounter surveys in old dune and other sand substrate habitats, plateau striped whiptails and lesser earless lizards were encountered most frequently, and eastern fence lizards (*Sceloporus undulatus*) were somewhat less common.

Collared lizards were captured most often in the rock habitat sampling site, while eastern fence lizards were most numerous in visual encounter surveys in rock habitats, followed by plateau striped whiptails and collared lizards. At the riparian sampling site, eastern fence lizards and southern spadefoots (*Spea multiplicata*) were the most common captures, while plateau striped whiptails were numerous in visual encounter surveys in riparian habitat (the highest numbers of any species we recorded in any habitat), and eastern fence lizards were also common.

## DISCUSSION

### *Sampling Effort*

We conducted fieldwork at Petrified Forest for one week every other week, so that sampling was spread uniformly across the active period for amphibians and reptiles, with approximately two sampling sessions per month. Except for the project start-up period, sampling effort was consistent across months (Table 1). Sampling effort for visual encounter surveys and night driving surveys was more variable, with effort concentrated during the times when observed amphibian and reptile activity was greatest (Table 5). In particular, night-time temperatures in May and June at Petrified Forest are relatively cold, and we observed very little activity at night, so we concentrated night driving sampling effort in the warmer months, from July through September. This also corresponded to the general time period of monsoon rains at Petrified Forest, which markedly increased amphibian activity.

### *Amphibian and Reptile Diversity*

Petrified Forest has moderate numbers of amphibian and reptile species, and is of particular interest for its grassland species. Noteworthy aspects of the fauna include three species of spadefoot toads: the plains spadefoot, which is near the western extent of its range in the Petrified Forest area; the New Mexico spadefoot;

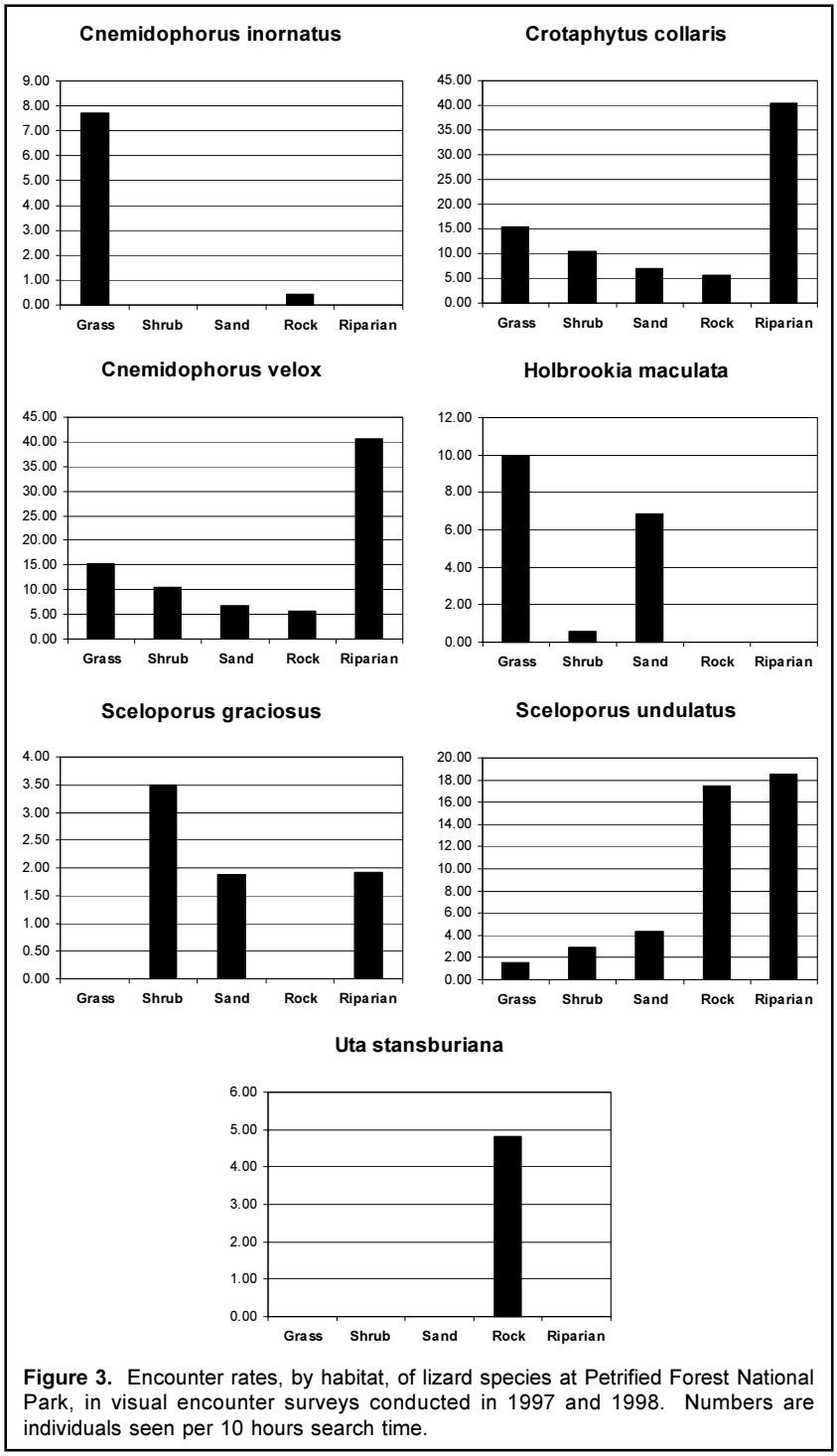


**Figure 3.** Encounter rates, by habitat, of lizard species at Petrified Forest National Park, in visual encounter surveys conducted in 1997 and 1998. Numbers are individuals seen per 10 hours search time.

**Table 5.** Night drive sampling of amphibians and reptiles at Petrified Forest National Park, by month and year, in 1997-1998. Distance driven varied among different months, so data have been adjusted to number of individuals per 1,000 km of driving.

| | 1997 | | | | 1998 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **SPECIES** | **JUL** | **AUG** | **SEP** | **OCT** | **MAY** | **JUN** | **JUL** | **AUG** | **SEP** |
| Tiger salamander | 0.0 | 1.0 | 1.0 | 7.0 | 0.0 | 0.0 | 1.6 | 0.9 | 0.0 |
| **Total:** | **0.0** | **1.0** | **1.0** | **7.0** | **0.0** | **0.0** | **1.6** | **0.9** | **0.0** |
| Plains spadefoot | 9.0 | 6.2 | 2.0 | 0.0 | 0.0 | 0.0 | 49.4 | 9.5 | 1.6 |
| Couch's spadefoot | 0.0 | 2.1 | 1.0 | 0.0 | 0.0 | 0.0 | 27.1 | 3.4 | 0.0 |
| New Mexico spadefoot | 99.1 | 10.3 | 10.8 | 21.1 | 0.0 | 0.0 | 189.5 | 12.9 | 17.6 |
| Great Plains toad | 36.0 | 13.4 | 4.9 | 7.0 | 0.0 | 0.0 | 38.2 | 15.5 | 1.6 |
| Red-spotted toad | 18.0 | 2.1 | 0.0 | 0.0 | 0.0 | 0.0 | 6.4 | 0.9 | 1.6 |
| Woodhouse's toad | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 1.6 | 0.9 | 0.0 |
| **Total:** | **162.2** | **34.1** | **20.5** | **28.2** | **0.0** | **0.0** | **313.7** | **43.9** | **22.4** |
| Glossy snake | 0.0 | 4.1 | 2.9 | 0.0 | 0.0 | 2.8 | 1.6 | 0.9 | 6.4 |
| Night snake | 9.0 | 8.3 | 4.9 | 7.0 | 11.5 | 7.0 | 8.0 | 4.3 | 1.6 |
| Common kingsnake | 0.0 | 3.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 3.2 |
| Milk snake | 0.0 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 1.6 |
| Striped whipsnake | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.6 |
| Gopher snake | 4.5 | 8.3 | 14.7 | 28.2 | 0.0 | 0.0 | 1.6 | 5.2 | 19.2 |
| Western rattlesnake | 9.0 | 6.2 | 7.8 | 14.1 | 0.0 | 1.4 | 1.6 | 5.2 | 3.2 |
| **Total:** | **22.5** | **34.1** | **31.3** | **49.3** | **11.5** | **11.2** | **12.7** | **18.9** | **36.8** |

and the Couch's spadefoot, which occurs as a disjunct population at Petrified Forest, well north of the main part of the species' range in Arizona. Also of note are three species of whiptail lizards. One of these (the little striped whiptail) is bisexual, while the other two (plateau striped whiptail and New Mexico whiptail) are unisexual and reproduce by parthenogenesis. Only the plateau striped whiptail was known from Petrified Forest or the northeastern Arizona area prior to our study. The little striped whiptail was probably once more widespread in the region, as it has declined in other parts of its range where grassland habitats have been lost or degraded (Bogan et al. 1998, Wright and Lowe 1965, 1968). The two small populations that we found at Petrified Forest are the only ones known from Apache and Navajo Counties in northeastern Arizona, and are separated from the nearest other populations by a distance of approximately 107 km (Persons and Wright 1999b).

The small population of New Mexico whiptails along the Puerco River floodplain within Petrified Forest is far west of the species' range along the Rio Grande drainage in New Mexico (Persons and Wright 1999a). Skin-grafting studies indicate that the lizards at Petrified Forest are genetically identical to populations in New Mexico (Persons and Wright, in prep.). Since the New Mexico whiptail is parthenogenetic, the population at Petrified Forest could have arisen from a single individual transported on the Atchison-Topeka and Santa Fe railroad (an east-west line that runs just north of the Puerco River through the park), or escaped from a vehicle

(Interstate Highway 40 links Petrified Forest with the heart of the New Mexico whiptail's range in central New Mexico).

From a conservation standpoint, the population of milk snakes at Petrified Forest is of interest. This small snake is very rare in the state of Arizona, known from only a few restricted locations scattered across the state. As with some of the other amphibians and reptiles at Petrified Forest, the occurrence of the milk snake at this location may be linked to the isolated area of healthy grassland protected within the park. This species and the little striped whiptail stand out as the two rarest and most restricted species protected within Petrified Forest National Park.

### *Completeness of Inventory*

That this study resulted in a nearly complete species inventory is supported by the fact that 22 of the 23 species documented (96%) were found after the first month and a half of field work, with varied field methods, intensive sampling effort, and extensive geographic coverage of the park. While there are a few additional species that could possibly occur at Petrified Forest (e.g., the many-lined skink, *Eumeces multivirgatus*, in the Puerco River floodplain, and the secretive southwestern black-headed snake, *Tantilla hobartsmithi*), only one species seems likely to have been missed during our surveys. The northern leopard lizard, *Gambelia wislizenii*, is known to occur in the general region of Petrified Forest (Stebbins 1985), and has been seen by one of us (TBP) 8 km west of the park boundary, in contiguous habitat (Puerco River flood plain). If this species occurs in the park, it is evidently rare and locally distributed. We surveyed many areas of suitable open shrub and shrub-grassland habitat, and found only the related collared lizard, a species usually associated with rocky situations.

### *Comparison of Methods*

To be most meaningful, comparisons of survey methods should include measures of cost. This provides a standard basis for comparison, and also reflects the fact that most surveys are conducted under limited budgets. The most expensive component of any survey is typically personnel time (e.g., Burbidge 1991), and that is particularly true of the observer-intensive methods used in this survey. For each sampling method, we recorded the amount of time that field personnel were actively engaged in that sampling method. We spent approximately 137 person-hours of effort on pitfall/array/coverboard sampling sites (including 25 hours for installation of the traps and boards), 136 hours on visual encounter surveys (combined time-constrained searches and general surveys), and 182 hours on night-driving surveys. If travel time to and from sampling sites is added in for pitfall/array/coverboard and visual encounter surveys (we did not record this precisely, because we were frequently engaged in more than one activity at a time), the amount of time we spent on the different methods is relatively close, with a slight bias toward night-driving.

Of the survey methods we used for amphibians and reptiles at Petrified Forest, the two most effective were visual encounter surveys and night driving. Night driving was by far the most effective method for amphibians and snakes (Table 3). Night

driving surveys found all of the seven species of amphibians that we documented at Petrified Forest, including two (red-spotted toad and Woodhouse's toad) that were not found with any other survey technique. Likewise, night driving recorded nearly five times as many individuals as all of the other techniques combined. The only other method that captured appreciable numbers of amphibians was drift fence arrays, in which we captured five amphibian species and just over 60 individuals. We recorded more individuals of each amphibian species during night-driving surveys than we did with all other methods combined.

The significant advantage of night-driving surveys for snakes was even more pronounced. Again, all seven species of snakes that we documented at Petrified Forest were recorded on night drives, including road-killed individuals of the diurnal striped whipsnake. By comparison, all other methods combined recorded only three snake species (Table 3). In terms of numbers of animals, we recorded 138 individual snakes on night drives, compared to a total of nine with all other methods combined.

Visual encounter surveys (combining time-constrained searches and general surveys) were most effective for lizards (Table 3). VES documented all nine lizard species known from Petrified Forest National Park, including two (little striped whiptail and New Mexico whiptail) that were not found with any other method. The drift fence/pitfall arrays and artificial coverboards provided comparable or better results for two relatively secretive species (the short-horned lizard and sagebrush lizard), but for most species we recorded substantially higher numbers of individuals during visual encounter surveys. This was especially true for the conspicuous, active, and wide-ranging whiptail lizards.

Besides their effectiveness for survey purposes, a significant advantage of visual surveys is that they have almost no other associated cost, compared to the significant materials cost and installation and maintenance time required for pitfalls, drift fences, and coverboards. However, there are problems associated with visual encounter surveys that must be taken into account. Because most animals observed are not caught, some individuals may be misidentified, or individuals may not be identified to species level (e.g., *Sceloporus* sp. and *Cnemidophorus* sp. in Table 3). With adequate training and experience, this should not be a serious problem for inventory purposes. More serious, if one wishes to quantify numbers of different species, is observer bias. This is a notorious problem with visual surveys (e.g., McDonald 1981), and extends both to differences among observers in the numbers of animals seen, and also (in unconstrained general surveys) to differences in the areas that different observers choose to focus their search efforts.

### *Habitat and Abundance*

Sampling methods that we used for amphibians and reptiles at Petrified Forest provide information on relative abundance, but the different methods have their own distinct biases. Inferences about relative abundance are strongest when different sampling methods yield the same rank order of species. Night driving provided the most extensive information on amphibians and snakes. For amphibians, rank abundance of the different species was similar between night driving and drift-fence arrays

(the only other method that yielded appreciable numbers of amphibians; Table 3). New Mexico spadefoots were the most abundant species encountered, followed by either Great Plains toad (night driving) or plains spadefoot (arrays). For snakes, no other method yielded more than six individuals, so night-driving data are the only yardstick that we have for species abundance. The four most numerous snakes encountered on night drives were, in order: gopher snake; night snake; western rattlesnake; and glossy snake. Relative abundance information from night driving has the important caveat that we do not know the propensity of different species to move onto the road, or to remain on the road for extended periods of time (one evident bias is that small, dark species such as the night snake are more likely to be overlooked than larger, lighter-colored species). Still, with appropriate caution in interpreting results, our night-driving data provides a good basis of comparison for future night-driving surveys. Night-driving surveys were not stratified by habitat, so we cannot discuss habitat associations for amphibians and snakes.

Our VES provided the most extensive data for lizards, but a comparison with data from trapping methods (pitfalls, drift fence arrays, and artificial cover) showed a conspicuous difference for the sagebrush lizard. Otherwise, VES and trapping yielded the same rank abundance. For VES this was, in order: plateau striped whiptail; eastern fence lizard; collared lizard; lesser earless lizard; and sagebrush lizard.

We broke down the data from VES and trapping by habitat (Table 4 and Fig. 3), and all species showed pronounced patterns of abundance in relation to habitat. Plateau striped whiptail, eastern fence lizard, and collared lizard had broad distributions across habitats, while side-blotched lizard was quite restricted. There were evident differences in abundance between the two methods, primarily for sagebrush lizard and plateau striped whiptail (Table 6).

**Table 6.** Most numerous amphibian and reptile species recorded by trapping methods (including pitfall traps, drift fence arrays, and artificial cover) and visual encounter surveys in different major habitats at Petrified Forest National Park in 1997-98. See also Table 4 and Figure 3.

| | Trapping | VES |
|---|---|---|
| **Grass** | Lesser earless lizard, Southern spadefoot | Plateau striped whiptail, Lesser earless lizard |
| **Shrub** | Sagebrush lizard, Plateau striped whiptail | Plateau striped whiptail, Sagebrush lizard |
| **Sand** | Plateau striped whiptail, Sagebrush lizard | Lesser earless lizard, Plateau striped whiptail |
| **Rock** | Collared lizard | Eastern fence lizard, Plateau striped whiptail |
| **Riparian** | Eastern Fence Lizard, Southern spadefoot | Plateau striped whiptail, Eastern fence lizard |

## *Biogeography*

Northeastern Arizona, including Petrified Forest, lies within a broad area of overlap of Great Basin and Great Plains biotic communities (Brown 1994). In addition, the region incorporates habitat elements derived from grasslands and deserts more characteristic of southern Arizona and northern Mexico. This mixing of biogeographic elements is reflected in the park's herpetofauna. The 23 species that we recorded can be categorized as having the main part of their range in either the Great Basin, Great Plains, the desert and grassland regions of the Southwest, eastern North America, or some combination of these (Table 7; Stebbins 1985). Species with more southern ranges dominate the fauna, while species characteristic of the Great Basin (sagebrush lizard), Great Plains (plains spadefoot), and eastern U.S. (milk snake) are near the limits of their range. Two of the species listed under "Other" in Table 7 have unique distributions: the New Mexico whiptail lizard is likely introduced (Persons

**Table 7.** Biogeographic patterns of the amphibian and reptile fauna of Petrified Forest National Park, Arizona. Species are categorized as occurring primarily in the Great Basin, Great Plains, southern deserts and grasslands, or eastern North America. Species listed as "other" have distributions that are widespread in western North America (tiger salamander, short-horned lizard, gopher snake, western rattlesnake), more restricted (Plateau Striped Whiptail on the southern Colorado Plateau), or probably introduced in the Park (New Mexico Whiptail). Species with distributions that are distinctly associated with two different areas are noted in both columns.

| Species | Great Basin | Plains | Southern | Eastern | Other |
|---|---|---|---|---|---|
| Tiger Salamander | | | | | X |
| Couch's Spadefoot | | | X | | |
| New Mexico Spadefoot | | | X | | |
| Plains Spadefoot | | X | | | |
| Woodhouse's Toad | | | | X | |
| Red-spotted Toad | | | X | | |
| Great Plains Toad | | X | X | | |
| Collared Lizard | X | | X | | |
| Short-horned Lizard | | | | | X |
| Lesser Earless Lizard | | X | X | | |
| Sagebrush Lizard | X | | | | |
| Eastern Fence Lizard | | | | X | |
| Side-blotched Lizard | X | | X | | |
| Little Striped Whiptail | | | X | | |
| Plateau Striped Whiptail | | | | | X |
| New Mexico Whiptail | | | | | X |
| Striped Whipsnake | X | | X | | |
| Gopher Snake | | | | | X |
| Common Kingsnake | | | X | X | |
| Milk Snake | | | | X | |
| Glossy Snake | | | X | | |
| Night Snake | X | | X | | |
| Western Rattlesnake | | | | | X |
| **TOTAL** | **5** | **3** | **12** | **4** | **6** |

and Wright 1999a), and the plateau striped whiptail lizard is largely restricted to the Colorado Plateau, having originated in this region through interspecific hybridization (Wright 1993).

In contrast to the predominance of southern amphibian and reptile species in the region, the flora of the Petrified Forest area is generally considered to be most closely allied with the Great Basin (Kearney and Peebles 1960, Gleason and Cronquist 1964, Brown 1994). This points to the role that other mechanisms, besides vegetation and climate, have played in the distribution of amphibians and reptiles that occur in the park. The most obvious factor is topographic barriers, such as the mountains of central Utah and the canyon of the Colorado River, which separate Great Basin species from northeastern Arizona. Hence, although the vegetation is primarily derived from Great Basin and Great Plains floras (Brown 1994), the close geographic proximity of Petrified Forest to the grasslands and deserts to the south has evidently been more important in determining the current composition of the park's herpetofauna.

## *Conservation*

Petrified Forest National Park protects a large area of native grassland, and aside from a portion of Wupatki National Monument north of Flagstaff, contains the only federally protected grasslands in the Little Colorado River basin of northeastern Arizona. Livestock grazing has had a profound impact on grasslands in the Southwest (e.g., Lowe 1964), and through exclusion of grazing Petrified Forest may also play an important role in the conservation of a number of regionally rare amphibian and reptile species, including Couch's spadefoot, little striped whiptail, and milk snake. Besides exclusion of livestock grazing, the current policy of night-time road closure at Petrified Forest may also play an important role in protecting the park's herpetofauna. Road mortality can have significant impacts on amphibians and reptiles, even in National Park areas (Rosen and Lowe 1994). Although the policy of night-time road closure at Petrified Forest was initiated to protect the park's significant geologic and cultural resources, local populations of nocturnal amphibians and reptiles also benefit.

## ACKNOWLEDGEMENTS

We thank the staff at Petrified Forest National Park, especially Superintendent Michele Hellickson, and Resource Management staff Mark DePoy, William Grether, Karen Bepler, and Pat Thompson, who supported this project from start to finish. We also thank park rangers Chuck Dorn, Rita Garcia, and Debbie Krueger for recording amphibian and reptile observations while they were on patrol. Many individuals helped with fieldwork for this study; Matthew Spille, Christoph Seger, and Claudia Seger-Thomschitz deserve special thanks for their time and effort in this regard. Roger Repp, the "herp king of southern Arizona," made the long trip north to help us look for milk snakes. Finally, we especially thank Maggs Rasmussen and Mary R.

Delfino-Debold of the Colorado Plateau Field Station for helping us through the budgetary and administrative mazes.

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